Simulations of Atmospheric Dynamics and Cloudiness In A Coastal Region

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LONG TERM GOALS

The goal of this project is to increase our understanding of the modification of complex atmospheric dynamics and thermodynamics due to the interaction of the air, sea, and land in a coastal region. This increased understanding will improve the forecasting of coastal weather on a wide spectrum of spatial and temporal scales.

OBJECTIVES

Specific project objectives include: 1) investigating the physical processes that lead to the formation, evolution, and dissipation of offshore fog; and 2) investigating the diurnal variability of the dynamics and cloudiness of the marine atmospheric boundary layer off the California and Oregon coasts. The project is supported by the Office of Naval Research, Marine Meteorology and Atmospheric Effects.

APPROACH

The approach proposed involved the use of selected atmospheric models and measurements from routine observations (surface stations, buoys), remote sensing instruments (wind profilers, satellites), and a special field program (Coastal Waves 96). For the study of offshore fog we used observations and modeling results. The observations include data from buoys, land stations, radiosondes, and satellites. A conceptual modeling was performed with a one-dimensional higher-order turbulence closure model (Koracin and Rogers 1990, Rogers and Koracin 1992, and Leipper and Koracin 1998). For the study of coastal dynamics and cloudiness we used results from a previous year's completed numerical experiment using Mesoscale Model 5 (MM5) (Koracin 1999). Simulations of hourly atmospheric dynamics and thermodynamics were performed for this region for all of June 1996. The model grid encompassed the coastal area from north of Cape Mendocino to the Los Angeles basin. The observational data for this task includes estimates of the cloud albedo along the west coast using GOES 9 digitized imagery.

WORK COMPLETED

We investigated a case of offshore fog along the U.S. west coast in April 1999. A comprehensive analysis included: characteristic synoptic evolution and estimation of subsidence; time series of wind, air and sea temperature from buoys; sea surface temperature according to satellite data; flow, stability, and structure; and evolution of the marine inversion as determined from radiosonde measurements over the land. A series of numerical simulations was performed to conceptually reproduce the formation and

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evolution of fog. Input and boundary conditions were based on aircraft measurements conducted in June 1996 (Rogers et al. 1998). Sensitivity tests were performed to investigate the importance of various parameters such as inversion properties, sea surface temperature, and subsidence on fog formation and evolution.

We analyzed a numerical experiment simulating hourly atmospheric dynamics over the U.S. California coast for all of June and July 1996 with high horizontal (9 km) and vertical (35 levels) resolution, and determined wind divergence and vorticity fields. Model evaluation was reported in Koracin et al. (1998b), Koracin (1999) and Koracin and Dorman (1999). Cloud albedo was estimated with 1 km^2 horizontal resolution from the 15-min reflectance data from the GOES 9 visible spectrum images for all of June 1996.

RESULTS

The fog event occurred in conjunction with the passage of an anticyclone into the northwestern U.S.; upper-air analysis indicated that subsidence existed along the California coast. Analysis of the satellite imagery and data from buoys indicated that the fog formed over the sea and that the near-surface air underwent a gradual cooling prior to fog formation. This cooling took place in the presence of a generally warmer sea surface. The gradual cooling was observed at buoys under cloud cover, while buoy data under clear skies did not exhibit the cooling trend. In order to conceptually understand this process and to test the hypothesis that the cloud-driven processes along the advection path initiated the air cooling over the generally warmer sea, we performed a series of numerical simulations. The simulations show that longwave cooling at the cloud top under subsidence conditions leads to the gradual air cooling and eventual fog formation. Gradual cooling is associated with a lowering of the cloud base and top (Fig. 1). Turbulence increases after the fog formation, and the entire fog layer is further cooled by several degrees. The fog growth and dissipation is mainly governed by radiative heat fluxes, subsidence, the strength of the inversion, and surface fluxes.

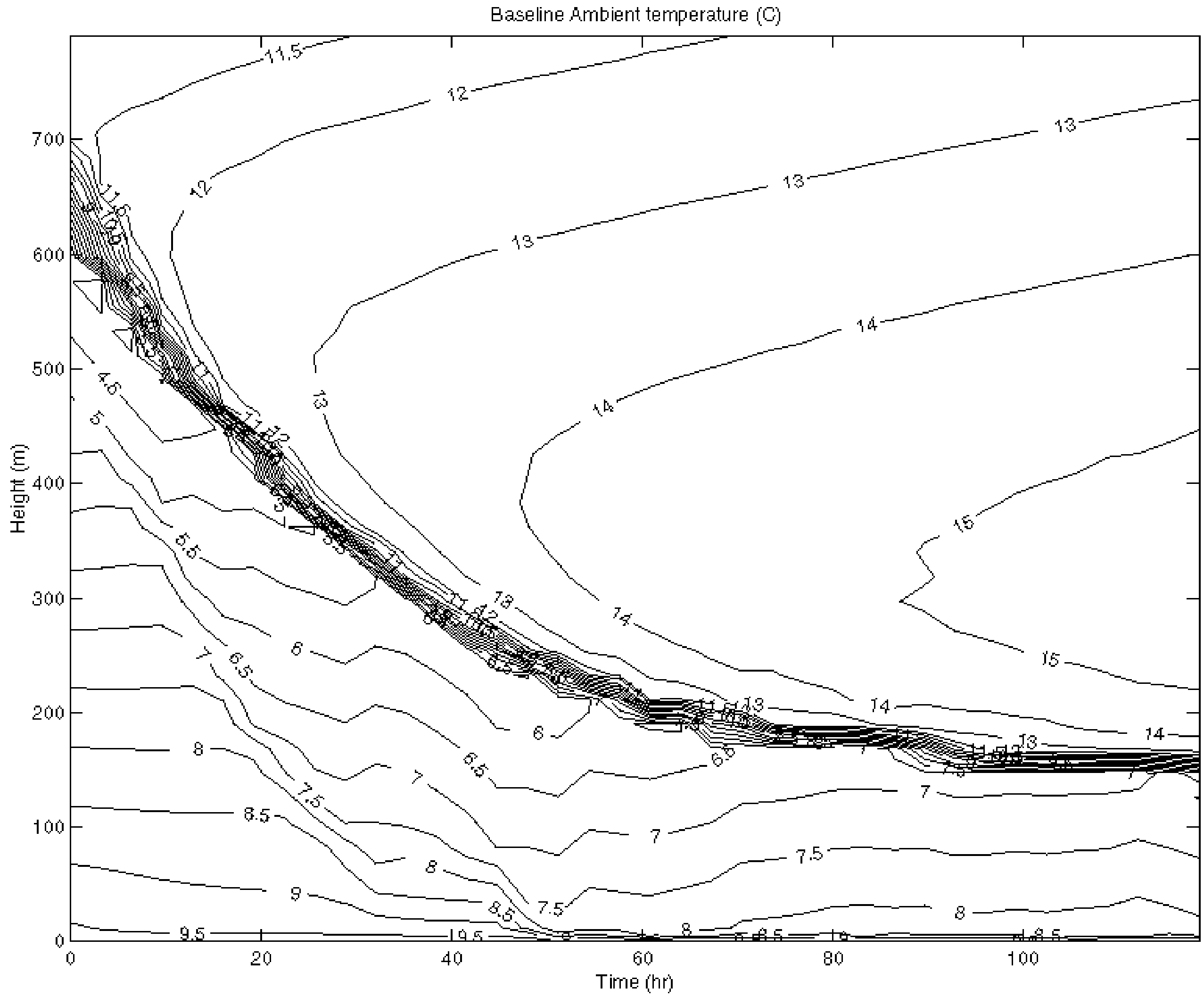
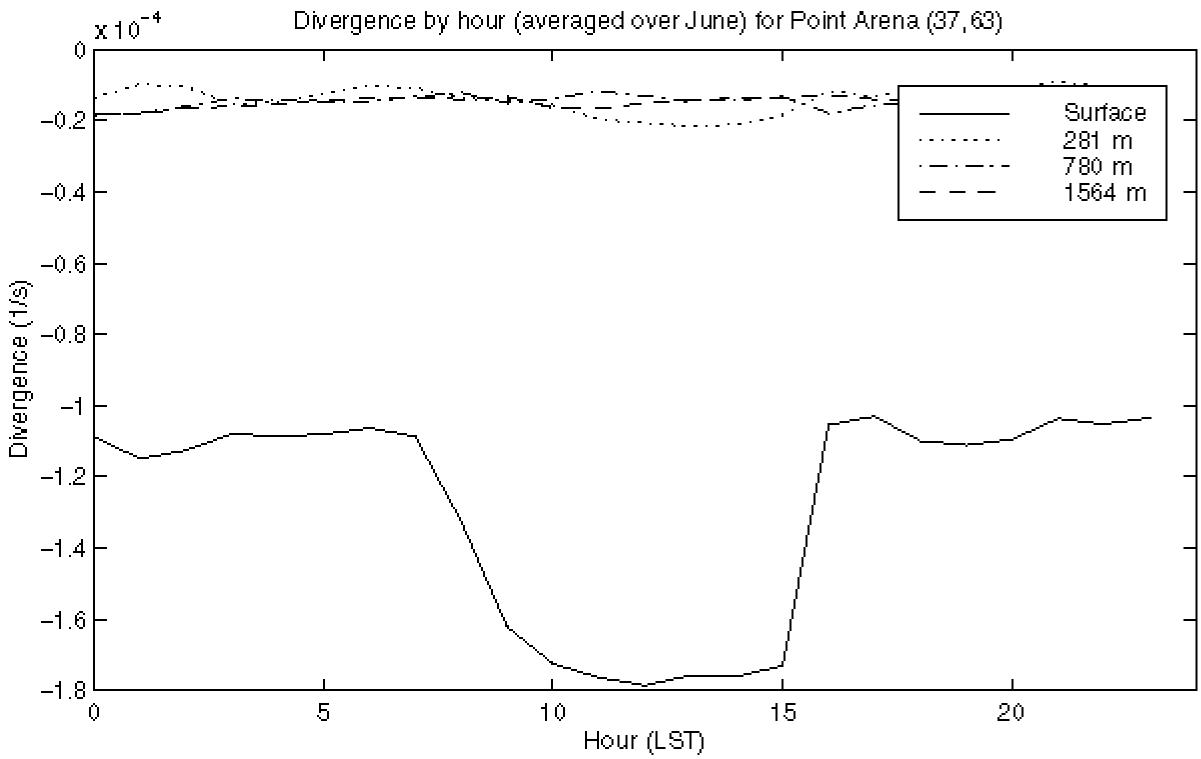


Figure 1: Contours of ambient temperature (ºC) for the baseline simulation. Contour interval is 0.5º.

Based on month-long monthly simulations, the study revealed the importance of diurnal effects on the dynamics of the marine layer along California and Oregon. An analysis of the wind and divergence fields suggests that there are five sets of persistent expansion fans and compression bulges dominating the coast from mid-Oregon to Point Conception. Wind and divergence fields in the expansion fans exhibit a strong diurnal variation with the greatest divergence in the middle of the day and much smaller values during nighttime (Fig. 2). In the compression bulges the divergence has the same diurnal trend, but is dominantly convergent or weakly divergent during the middle of the day. Vertically, in an expansion fan, the maximum divergence is greatest at the surface, decreases with height while keeping the same diurnal pattern, and reverses to convergence a few hundred meters above the marine layer. At about 1500 m and higher the divergence is much weaker and varies mainly synoptically. This distinct diurnal behavior of the divergence field rapidly attenuates in the offshore direction and becomes an order of magnitude smaller at approximately 100 km off the coast. Further offshore there are organized structures in the divergence field.



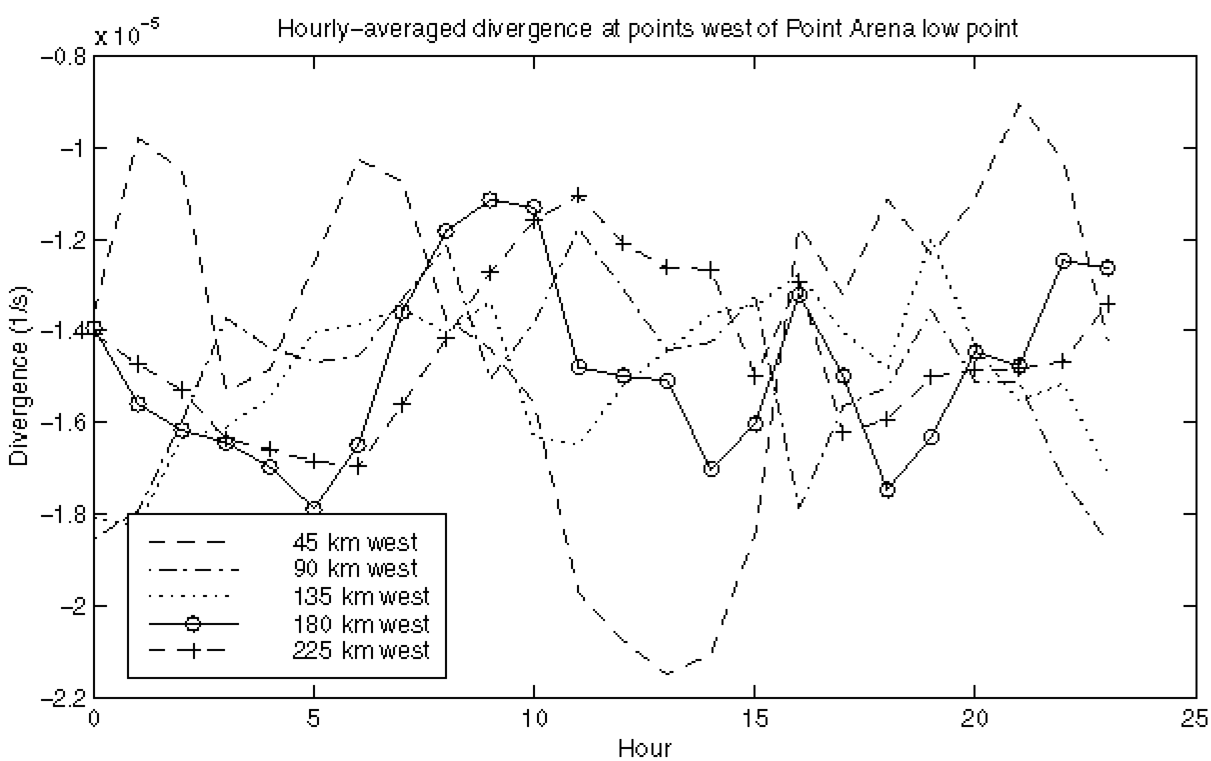


Fig. 2 Diurnal trend of MM5 modeled convergence at 20m, 700m, and 1500m AGL (upper panel) and at distances off shore of the lee of Point Arena.

An analysis of satellite data has revealed spatial structures of cloud albedo similar to the spatial structures of the wind and divergence fields in the near-shore zone. The cloud albedo structure in the five sets of expansion fans and compression bulges matched those in the simulated wind and divergence fields. Moreover, the diurnal trend in cloud field in all expansion fans and compression bulges matched those in the divergence field, with the minimum at midday and the maximum in the nighttime. By this type of comparison, modeled dynamics were evaluated using the observed cloud field determined from satellite data.

IMPACT/APPLICATIONS

The results of this study improve the predictability of wind, turbulence, clouds, fog, and stable internal boundary layers in coastal areas. This will aid in decision making and in the performance of low-level airborne and sea-based naval operations. The results may be applied to other coastal areas worldwide.

TRANSITIONS

Dr. Le Ly of the NPS has used the MM5 wind fields developed by this study to drive the Princeton ocean model for the mesoscale ocean simulations in Monterey Bay (Ly et al. 1999). We simulated a strong wind (bora) case in the Adriatic Sea. The results have been used by our collaborators from Croatia (the Oceanographic Institute in Split) to drive an ocean model. They were able to reproduce a vortex observed in the northern Adriatic (Beg Paklar et al. 1999). We are investigating the significance of gravity waves on the west coast with Dr. Clive Dorman. Collaborators from the University of Uppsala (Mr. Ragoth Sundarajan) and the University of Stockholm (Dr. Michael Tjernström) are using our month-long simulation results to study the transport and dispersion of atmospheric pollutants on the U.S. west coast (Sundarajan et al. 1999). We also collaborate with Dr. Gunilla Svensson of the University of Stockholm on simulations of the cloudiness transition observed in ASTEX (Svensson et al. 1999).

RELATED PROJECTS

We are collaborating with Drs. Wendell Nuss and Le Ly (NPS, Monterey), Dr. Clive Dorman and Dr. David P. Rogers (Scripps, San Diego), and Dr. Michael Tjernström (Uppsala University, Sweden), all of whom have ONR funding. The P.I. for this project, Dr. Koracin, has another ONR funded project (N00014-96-1-1235), which focuses on turbulence transfer over inhomogeneous surfaces and was also applied to the evolution of marine clouds. The results from these two studies motivated the development of a proposal to DOD-ONR (Drs. S. Chai and D. Koracin, co-P.I.s) focusing on modeling the dispersion of vapor and aerosol particulates in complex terrain, which is also in progress. The P.I. for this project was a P.I. on the DoD – DURIP – ONR awarded proposal to purchase a supercomputer SGI Origin 2000 with 16 processors. This award will significantly enhance mesoscale modeling capabilities of the P.I. and his collaborators at DRI. Our proposal to Scripps (Dr. D. Koracin as a P.I.) to support their NSF-COOP project focusing on the atmospheric and oceanic processes in Bodega Bay has been accepted. The P.I. on this project is also a P.I. (with co P.I.s Drs. Steve Chai and Melanie Wetzel, and Mr. Jeff Tomer) on a project entitled "Enhancement of high-resolution numerical simulations of atmospheric and dispersion processes using a multi-processor computer," which was awarded by DoD-DURIP.

REFERENCES

Beg Paklar, G., V. Isakov, D. Koracin, V. Kourafalou and M. Orlic, 1999: A case study of bora-driven flow and density changes on the Adriatic shelf (January 1987). Manuscript in preparation.

Koracin D., 1999: Simulations of atmospheric dynamics along the U.S. California coast. Manuscript in preparation.

Koracin, D., and C. Dorman, 1999: Marine atmospheric boundary layer divergence and clouds along California in June 1996. To be presented at the 3rd Conference on Coastal Atmospheric and Oceanic Prediction and Processes. Manuscript in preparation.

Koracin, D., M. Tjernström, G. Svensson, and A. Andrén, 1998a: Turbulence parameterization and nonlocal mixing in the inhomogeneous atmospheric boundary layer. To be presented at the 13th Conference on Boundary Layers and Turbulence, Phoenix, Arizona, 11-16 January 1998. Paper 8.2.

Koracin, D., J. Frye, V. Isakov, D.F. Leipper and P. Saha, 1998b: Simulations of atmospheric dynamics during the Coastal Waves Program in June 1996. Presented at the Second Conference on Coastal Atmospheric and Oceanic Prediction and Processes, Phoenix, AZ, 11-16 January 1998. Paper 4.7, 137-142.

Koracin, D., V. Isakov, and D.F. Leipper, 1998c: Simulations of the sea breezes on the central U.S. California coast. Presented at the Seventh International Conference - HYDROSOFT, Como, Italy, 16-18 September 1998. Published in *Hydraulic Engineering Software*, Ed. W.R. Blain, Wessex Institute of Technology Press, 624pp.

Koracin, D., V. Isakov and J. Frye, 1998d: A Lagrangian particle dispersion model (LAP) applied to transport and dispersion of chemical tracers in complex terrain. Presented at the Tenth Joint Conference on the Applications of Air Pollution Meteorology, Phoenix, AZ, 11-16 January 1998. Paper 5B.5, 227-230.

Koracin, D., V. Isakov, and J. Frye, 1999: "A method of evaluating atmospheric models using tracer measurements". *J. Appl. Meteor.* (in press)

Koracin, D., V. Isakov, and L. Mendez-Nuñez, 1998: A cloud-resolving model with the radiation scheme based on the Monte Carlo method. *Atmospheric Research* (47), 437-459.

Koracin, D., J. Lewis, W. Thompson, and C. Dorman, 1999: Observation and modeling of offshore fog along the California coast. To be presented at 3rd Conference on Coastal Atmospheric and Oceanic Prediction and Processes. Manuscript in preparation.

Koracin, D., and D. P. Rogers, 1990: Numerical simulations of the response of the marine atmosphere to ocean forcing. *J. Atmos. Sci.*, **47**, 592-611.

Leipper, D.F., and D. Koracin, 1998: Hot spells and their role in forecasting weather events on the U.S. west coast. Presented at the Second Conference on Coastal Atmospheric and Oceanic Prediction and Processes, Phoenix, AZ, 11-16 January 1998. Paper 4.5, 127-132.

Ly, L., P. Luong, J. D. Paduan, and D Koracin, 1999: Response of the Monterey Bay Region to Wind Forcing by an Atmospheric Model. . To be presented at the 3rd Conference on Coastal Atmospheric and Oceanic Prediction Processes, New Orleans, LA, November 3-5, 1999

Rogers, D. P., and D. Koracin, 1992: Radiative transfer and turbulence in the cloud-topped marine atmospheric boundary layer. *J. Atmos. Sci.*, **49**, 1473-1486.

Rogers, D. P., C. E. Dorman, K. A. Edwards, I. M. Brooks, W. K. Melville, S. D. Burk, W. T. Thompson, T. Holt, L. M. Ström, M. Tjernström, B. Grisogono, J. M. Bane, W. A. Nuss, B. M. Morley, and A. J. Schanot, 1998: Highlights of Coastal Waves 1996. *Bull. Amer. Meteorol. Soc.*, **79**, 1307-1326.

Sundarajan, R., D. Koracin, and M. Tjernstrom, 1999: Simulation of Spatially-Inhomogeneous Marine Intrusions Along the U.S. California Coast During the Warm Season. To be presented at the

3rd Conference on Coastal Atmospheric and Oceanic Prediction Processes, New Orleans, LA, November 3-5, 1999

Svensson, G., M. Tjernström, and D. Koracin: The sensitivity of a stratocumulus transition: model simulations of the ASTEX first Lagrangian. Manuscript being reviewed.